Time Projection Chamber with Triple GEM and Highly Granulated Pixel Readout

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on behalf of the LCTPC-Collaboration

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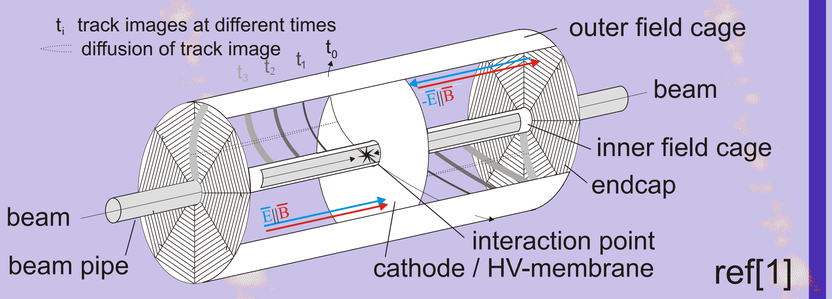
Time Projection Chamber (TPC)

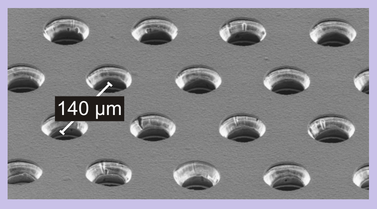


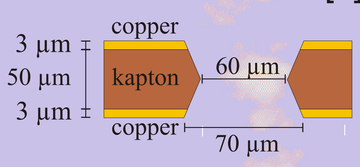
ref[1]

- Good spatial resolution
- Large number of measurements
- Good dE/dx measurement
- Low material budget (3% X_0)
- True 3D detector
- High granularity
- No ambiguities
- Homogeneous

Gas Electron Multiplier (GEM)

ref[2]

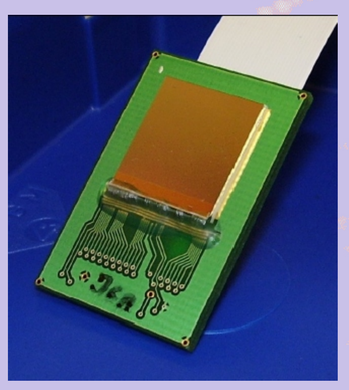




- Ion backflow is reduced significantly
- Small pitch of gas amplification regions
- Strong reduction of E×B effects
- Measurement of direct e^--collection
- Very fast signal (no ion tail)
- No directional preference, true 2D geometry

Timepix Chip

ref[3]



256 × 256 pixels
Pixel dimension: 55 × 55 µm²
Chip dimension: 1.4 × 1.4 cm²
Each pixel can be set to one of these modes:

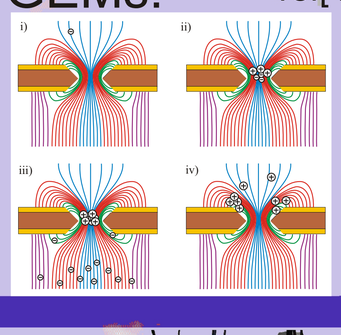
- Hit counting
- TOT = time over threshold gives integrated charge
- Drift time
- Hit/no-hit

Current limitations will be improved in next design (2010)
Timepix-2: multi-hit capable, 2 modes per pixel

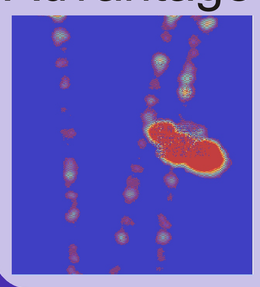
Advantage of combining a TPC and GEMs:

ref[4]

- Continuous readout is possible due to reduction of ion backflow
- Small amplification patterns improve spatial and momentum resolution: reduction E×B effect, no angular wire effect, smaller angular pad effect
- Improves double track resolution due to reduced signal width (direct e^--collection)



Advantage of combining GEMs and pixelized ASICs:



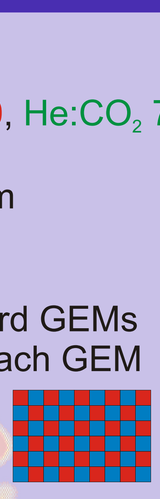
- High granularity allows tracking of single primary electrons
  => improves spatial resolution due to higher statistics
- Identification of δ-electrons and kinks of multiple scattering
  => improves spatial resolution by removing outliers
- dE/dx measurement through counting primary clusters
  => reduced statistical fluctuations improve energy resolution
- Reduced material budget of endcap

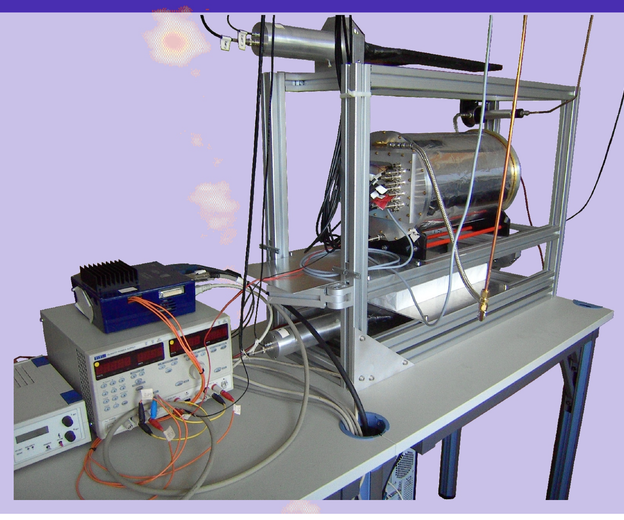
ref[5], ref[6]

Prototype detector:

ref[7]

- Gas mixtures: Ar:CO_2 70:30, He:CO_2 70:30
- Electric drift field 500 V/cm
- Maximum drift length: 26 cm
- Inner diameter : 23 cm
- Material budget: 1% X_0
- Gas amplification: 3 standard GEMs with 1mm spacing below each GEM
- Readout: single Timepix with checkerboard pattern of TOT and Time





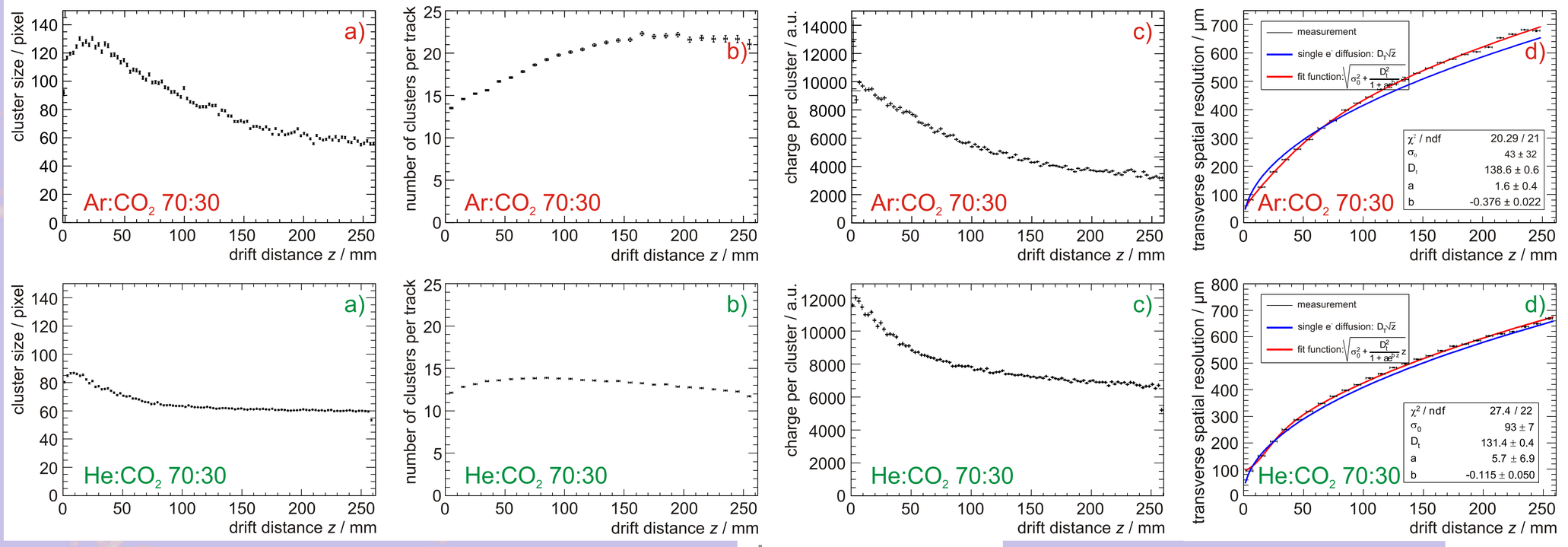
Observing declustering of single electrons

Graph a) cluster size
Short drift distances:
- cluster size increases with z
- multielectron hits become wider

Longer drift distances:
- hit sizes decrease with z
- more and more individual electrons become separable

Graph b) number of clusters per track increases, if more clusters can be separated

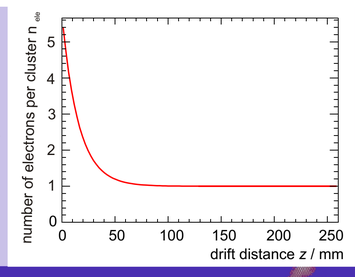
Graph c) charge per cluster decreases, if more clusters can be separated



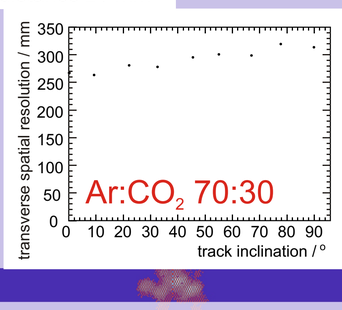
Effects of declustering are enhanced for Ar based gas mixtures,since Argon has higher primary ionization:
$n_{T,Ar:CO2}$ = 90 e^-/cm
$n_{T,He:CO2}$ = 15 e^-/cm

Transverse spatial resolution:

Graph d) dominated by single electron diffusion $\sigma(z) = \sqrt{D_t^2 z}$
but: declustering reduces the number of electrons per cluster
$n_{ele} = 1 + a\, e^{bz}$ (see graph on right side)
=> $\sigma = \sqrt{\sigma_0^2 + D_t^2/(1 + a\, e^{bz})}$



only very weak dependence of the transverse spatial resolution on the track inclination in the readout plane were found

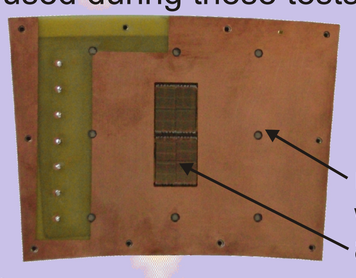


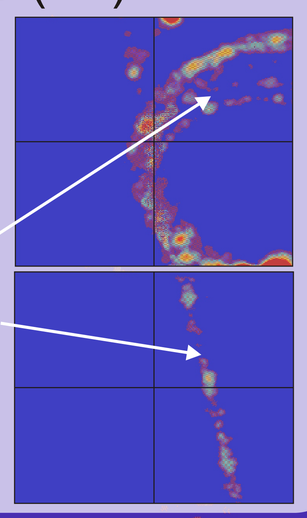
References:

[1] D.R. Nygren, PEP-198 (1975).
[2] F. Sauli et al., Nucl. Instr. and Meth. A 386 (1997) 531.
[3] X. Llopart et al., Nucl. Instr. and Meth. A 581(2007) 485-494.
[4] J. Kaminski et al., Nucl. Instr. and Meth. A 535(2004) 201-204.
[5] P. Colas et al., Nucl. Instr. and Meth. A 535 (2004) 506-510.
[6] A. Bamberger et al., Nucl. Instr. and Meth. A 572 (2007) 157-159.
[7] J. Kaminski et al., IEEE NSS 2008, Conference Record

Measurements with Large Prototype (LP)

(for LP see Poster by Patrick Conley, U. Victoria)
An endcap module with 8 Timepix chips has been built and tested in the Large Prototype of the LCTPC-Collaboration at DESY
An electron beam with an energy of 5 GeV was used during these tests.





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